[0046] The microcontroller **402** is coupled to a control panel **404** to provide user control and information on the desired mode of operation. The control panel includes a set of switches that can be read through the input buffers **418** of the microcontroller. The control panel also may have a display panel or lights to display information such as operational mode and battery state. The control panel also includes means to adjust the strength of assistance and resistance in order to customize the forces to the ability of the user. Another embodiment of the control panel is a wired or wireless connection port to a handheld, laptop or desktop computer. The connection port can also be used to communicate diagnostic information and previously stored performance information.

[0047] Outputs of the microcontroller, provided from the output buffers **426**, are directed in part to the actuator **12** through a power driver circuit **410** and in part to the control panel **404**. In the preferred embodiment, the driver circuit converts the outputs to high voltage phases to drive an electrostatic actuator. The power driver circuit includes transformers and rectifiers to step up a-c waveforms generated by the microcontroller.

[0048] Note that an actuator as shown in **FIGS. 2***d-f* allows also pulsed signals rather than sinusoidal wave shaped signals and, accordingly, the power drivers are configured to generate high-voltage multi-phase pulsed signals. Moreover, in instances where the actuator is a DC motor, servomotor, or gear motor, the power driver circuit is designed to generate high-current multi-phase signals.

[0049] When the operation mode of the muscle assistance device is set to apply a force that opposes the motion of the joint, the energy input from that 'external' force must be absorbed by the control circuit. While this energy can be dissipated as heat in a resistive element, it is preferably returned to the battery in the actuator power supply **408** via a regeneration braking circuit **412**. This concept is similar to "regenerative braking" found in some types of electric and hybrid vehicles to extend the operation time before the battery needs to be recharged.

[0050] The microcontroller **402** receives analog sensor information and converts it to digital form with the analog-to-digital converters **428**. The joint angle sensor **414** provides the joint angle through a variable capacitor implemented as part of the electrostatic actuator (see e.g., **FIGS. 2***d-f*). Alternatively, joint angle can be supplied by a potentiometer or optical sensor of a type known in the art.

[0051] When the invention is used to assist leg extension, the muscle stress sensor **416** is implemented as a foot-pressure sensor wired to the active brace. This sensor is implemented with parallel plates separated by a dielectric that changes total capacitance under pressure. In one implementation the foot sensor is a plastic sheet with conductive plates on both sides so that when pressure is applied on the knee the dielectric between the plates compresses. The change in the dielectric changes the capacitance and that capacitance change can be signaled to the microcomputer indicating to it how much pressure there is on the foot. There are pressure sensors that use resistive ink that changes resistance when pressure is applied on it. Other types of pressure sensors, such as strain gauges can be alternatively used to supply the pressure information. These sensors are configured to detect the need or intention to exert a muscle. For example, the foot pressure sensor in conjunction with joint angle sensor detects the need to exert the quadriceps to keep the knee from buckling. Other types of sensors, such as strain gauges, could detect the intension by measuring the expansion of the leg circumference near the quadriceps. In another embodiment, surface mounted electrodes and signal processing electronics measure the myoelectric signals controlling the quadriceps muscle. When the invention is used for other muscle groups in the body, appropriate sensors are used to detect either the need or intention to flex or extend the joint being assisted. It is noted that there is a certain threshold (minimum amount of pressure), say 5 pounds on the foot, above which movement of the actuator is triggered.

[0052] As further shown in **FIG. 4**, there are additional analog signals from the actuator **12** to the microcontroller **402** (via the analog-to-digital converters **428**). These signals communicate the fine position of the actuator to give the microcontroller precise information to determine which phase should be driven to move the actuator in the desired direction.

[0053] Power for the muscle assistance device comes from one or more battery sources feeding power regulation circuits. The power for the logic and electronics is derived from the primary battery (in the power supply **408**). The batteries-charge state is fed to the microcontroller for battery charge status display or for activating low battery alarms. Such alarms can be audible, visible, or a vibration mode of the actuator itself. Alternatively, a separate battery can power the electronics portion.

[0054] Turning now to **FIG. 5**, the operation of the muscle assistance device is illustrated with a block diagram. The algorithm in this diagram is implemented by embedded program code executing in the microcontroller. In the first step of **FIG. 5**, the user selects a mode of operation **502**. The modes include: idle **506**, assist **508**, monitor **510**, rehabilitate **512**, and resist **514**.

[0055] In the idle mode **506**, the actuator is set to neither impede nor assist movement of the joint. This is a key mode because it allows the device to move freely or remain in place when the user does not require assistance or resistance, or if battery has been drained to the point where the device can no longer operate. Idle mode requires the actuator to have the ability to allow free movement either with a clutch or an inherent free movement mode of the actuator, even when primary power is not available.

[0056] In the monitor mode **510**, the actuator is in free movement mode (not driven), but the electronics is activated to record information for later analysis. Measured parameters include a sampling of inputs from the sensors and counts of movement repetitions in each activation mode. This data may be used later by physical therapists or physicians to monitor and alter rehabilitation programs.

[0057] In essence, there are instances when there is no need for any assistance from the active muscle support device and free movement of the leg is required. This is one reason for using an electrostatic actuator, rather than a standard DC motor. A standard DC motor or servo motor, needs to run at a fairly high speed to develop torque and requires a gear reduction between the motor and the load. Obviously, rotation of the knee (and actuator) does not complete a full circle, and the joint moves at a speed of about